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ABSTRACT

This is one of a series of units for environmental education developed by the Highline Public Schools. Designed for secondary school science classes, the unit is concerned with particulate matter of air pollution. Five lessons are included. The lessons include construction of equipment and collecting data. (RH)

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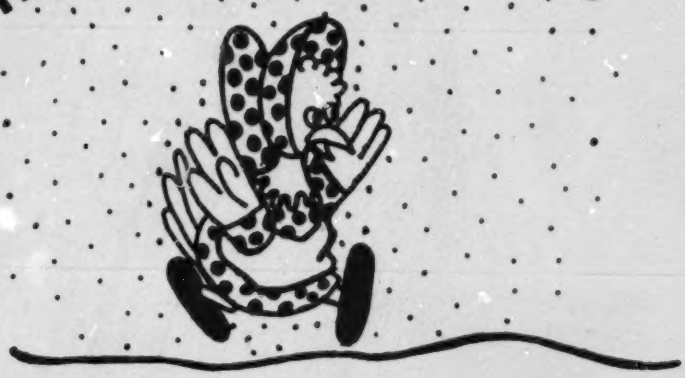
THOMPSON PAK

THE SKY IS FALLING



A study of particulates...

by Dennis W. Thompson

A Environments' Learning Experience for 7th-12th grade levels. One of many "ELE PAKS" available for all areas.

Project ECOLogy, Title III, ESEA
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P. O. Box 66100
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SE 021 474

BACKGROUND INFORMATION

WHAT IS AIR POLLUTION?

Gases, liquids, or solids that are present in the atmosphere and can be harmful to man, animals, plants, and property.

WHAT ARE PARTICULATES?

Air pollution in the form of solid or liquid droplets.

HOW BIG ARE PARTICULATES?

From less than one micron to around 100 microns--one micron is 1/1,000 of a millimeter or 1/25,000 of an inch.

HOW ARE PARTICULATES HARMFUL?

They can increase fog, absorb the suns heat, cause cancer, help carry dangerous gases deep into the lungs, and other harmful things.

WHAT ARE THE MAIN SOURCES OF PARTICULATES?

In order, power plants and space heating, industrial processes, transportation, solid waste disposal, and others.

WHAT QUANTITIES OF PARTICULATES EXIST IN THIS COUNTRY?

In the winter in New York City, 335 tons fall per day; even Kansas City get 67 tons per day in the winter.

HOW CAN PARTICULATES BE CONTROLLED?

Removal by using filters, electrostatic precipitatos, or cyclones; emission and evaporative controls on transportation equipment; and burying or efficiently incinerating solid wastes.

Much information is available on particulates specifically and even more is available on air pollution in general. It is impossible to list all of these here if only for the reason that much new information becomes available daily. Also the information runs the gamut from simplified and general to complex and specialized. Selecting such information would depend on the purpose for using this learning experience--it could be used as an integral part of a lesson on air pollution, or it could be made available for research by students working on individual projects, or it could be used for some combination of these purposes. Selecting the proper information would depend on which purpose was selected, and how far the teacher or student wished to pursue the project.

The following basic information is available from the Educational Resource and Administrative Center, Highline Public Schools. Included in the references are addressed where more information can be obtained.

1. Volunteers for Air Monitoring Project (VAMP), the Cooperative Science Education Center, Inc., under subcontract to Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

2. "Air Pollution Primer," National Tuberculosis and Respiratory Disease Association, 1971, New York, New York. (A catalog of printed and audio-visual materials is available from local Christmas Seal Associations.)

3. "The Sources of Air Pollution and Their Control," U. S. Department of Health, Education, and Welfare, Public Health Service Publication No. 1548. (For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 - price 35¢.)

4. "The Affects of Air Pollution," U. S. Department of Health, Education and Welfare, Public Health Service Publication No. 1556 (revised 1967). (For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington D. C. 20402 - price 45¢).

5. "Conserving Our Waters and Clearing the Air," American Petroleum Institute, 1801 K Street N. W., Washington, D. C. 20006 (free of charge).

6. "Testing for Air Pollution," U. S. Department of Agriculture, Science Study Aid No. 5, 1972. (For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington D. C. 20402 - price 10¢, Stock Number 0100-1619.)

The E.R.A.C. also has a more extensive list of ecology oriented materials. Included on this list, and listed below, are some sources of bibliographies.

Science for Society, a Bibliography. Third ed. American Association for the Advancement of Society, 1972.

The Environment Index; a guide to the key environmental literature of the year. Environmental Information Center, 1972.

Ecology (price list 88) Supt. of Docs., USGPO, 1972.

A Compilation of Materials for Environmental Education. Rev. Ed. National Education Association and National Park Service, 1972.

Environmental Learning Resource Kit. Washington State Dept. of Ecology, 1972.

Free Educational Information and Materials. Earth Science Educational Program, 1971.

Aids to Environmental Education, 7-9 and 10-14. Massachusetts Audubon Society.

Ecosources. A monthly list compiled by Janet Woerner, Freeland Community Schools, Freeland, Michigan for the price of a self-addressed, stamped envelope.

CONCEPTUAL OVERVIEW OF UNIT

This learning unit consists of lessons on particulates and, along with the lesson, an experiment to determine the quantity of particulates which exist in selected areas. The sections consist of:

1. What are Particulates? Making of the guards
2. What are the Effects of Particulates? Making of Adhesive Foils and Assembly of the Monitors
3. What are the Sources of Particulates? Distribution of Monitors
4. How Heavy are Particulate-Falls? Evaluation of Monitors
5. How can Particulates be Controlled?

NOTES TO THE TEACHER

As mentioned in the section on background information, this experience can be approached in different ways:

1. The students could be provided with the ready-made monitors, take them home and expose them, and then evaluate the monitors in the classroom.

2. Some or all of the students could help in the preparation of the monitors in addition to the exposing and the evaluation of the results. This would help in removing some of the tedious work from the teacher, and at the same time it should help the students appreciate some of the aspects of setting up a scientific experiment.

3. A student, or a few students, could organize and perform all of the tasks listed, with the teacher acting only in an advisory capacity. Although this would probably be possible only with students in the upper grades of high school, it would provide them with an invaluable experience in the conducting and managing of a scientific experiment.

A selection of one of these approaches would affect how the experience would be presented in the classroom. If the students are to simply take completed monitors home for exposing, this material should probably be included in a lesson to give it some meaning. The same thing probably holds true even if the students help in the construction of the monitors. But if a few students handle the entire experience as an independent project, no lesson would be needed. A report to the class by the project's leaders on the experiment's conclusion would be a good idea, however.

Since the time of exposure of the monitors is 30 days, it could be assumed that the duration of this experience would last from 7 to 9 weeks if the entire experience is to be performed. If the students are given completed monitors, 5 weeks should be sufficient to cover the exposing and evaluating.

It should be emphasized that changes to the procedures mentioned herein that could simplify construction of the monitors or increase their reliability would be welcomed. Please note that in a few places in the description of the experience, alternative methods are suggested. It should be pointed out that these alternatives have not been tried. If the alternatives look more promising from your viewpoint, then try them, along with any others that you may think of or that your students may suggest.

MASTER MATERIALS LIST

aluminum sheets, 6"x4"x.032", one for each monitor
G.E. Silicone Adhesive, SR-516, get the smallest amount you can - a little goes a long way
toluene, for use as a thinner for the adhesive
aluminum foil, approximately 1 3/16" x 2 15/16" x .005" minimum, one for each monitor
paint brush, 1" wide - these are to be discarded after use
acetone, trichloroethylene, or some other organic cleaner
(The above five items could possible be replaced with Fasson's Pli-A-Print r-135 adhesive paper, with protective release liner M78 - obtainable from Fasson Products Division of Avery Paper Co., 250 Chester Street, Painesville, Ohio)
plastic bag, large enough to hold the guard, one for each monitor
paper clips, at least two for each monitor
paper bag or cardboard box to hold the plastic bag with the guard inside
map of area monitored
graph paper
map pins with colored heads, small colored flags, or some other marking device

LESSON 1

CONCEPT: Small pieces of liquids and solids in the air are called Particulates

MATERIALS: aluminum sheets, 6"x4"x.032" for each guard needed. (alternately, some method could be developed to make the guards from plastic)

PROCEDURE: *"We are going to study about particles, and at the same time, we will make some equipment to measure the quantity of particulates which exist in the air in our school area."*

1. *"What are particulates?"* (air pollution in the form of small particles of solids and liquids)

2. *"How big are particulates?"* (from less than one micron - 1/1,000 of a millimeter of 1/25,000 of an inch - to around 100 microns)

3. *"What are some other names for particulates, and how big are they?"*
   a. aerosols, which can move as easily as gases - less than 1 micron
   b. smoke, which is both solid and liquid - less than 1 micron
   c. fume, solids only - less than 1 micron
   d. mist, liquids only - up to 100 microns
   e. dust, solids only - greater than 1 micron

4. *"How do these sizes compare to other more commonly known things?"*
   a. viruses - 0.01-0.1 microns
   b. bacteria - 1-25 microns
   c. fog - 5-60 microns
   d. raindrops - 400-5,000 microns

5. Particulates larger than 10 microns are visible to the naked eye.

6. Now lets make the protective guards for our experiment using the following instructions.

The purpose of the guards is to provide a support for the adhesive foils which will be removed after exposure and to protect the adhesive foils from large foreign objects such as birds or twigs, and to provide a method for attaching the adhesive foils to some stationary support. These functions require that the guards be made quite strong so as to not be affected by winds or other forces. Since the guards are to be exposed to all atmospheric conditions for the 30 day monitoring period, they must be made from some material that is resistant to these conditions.

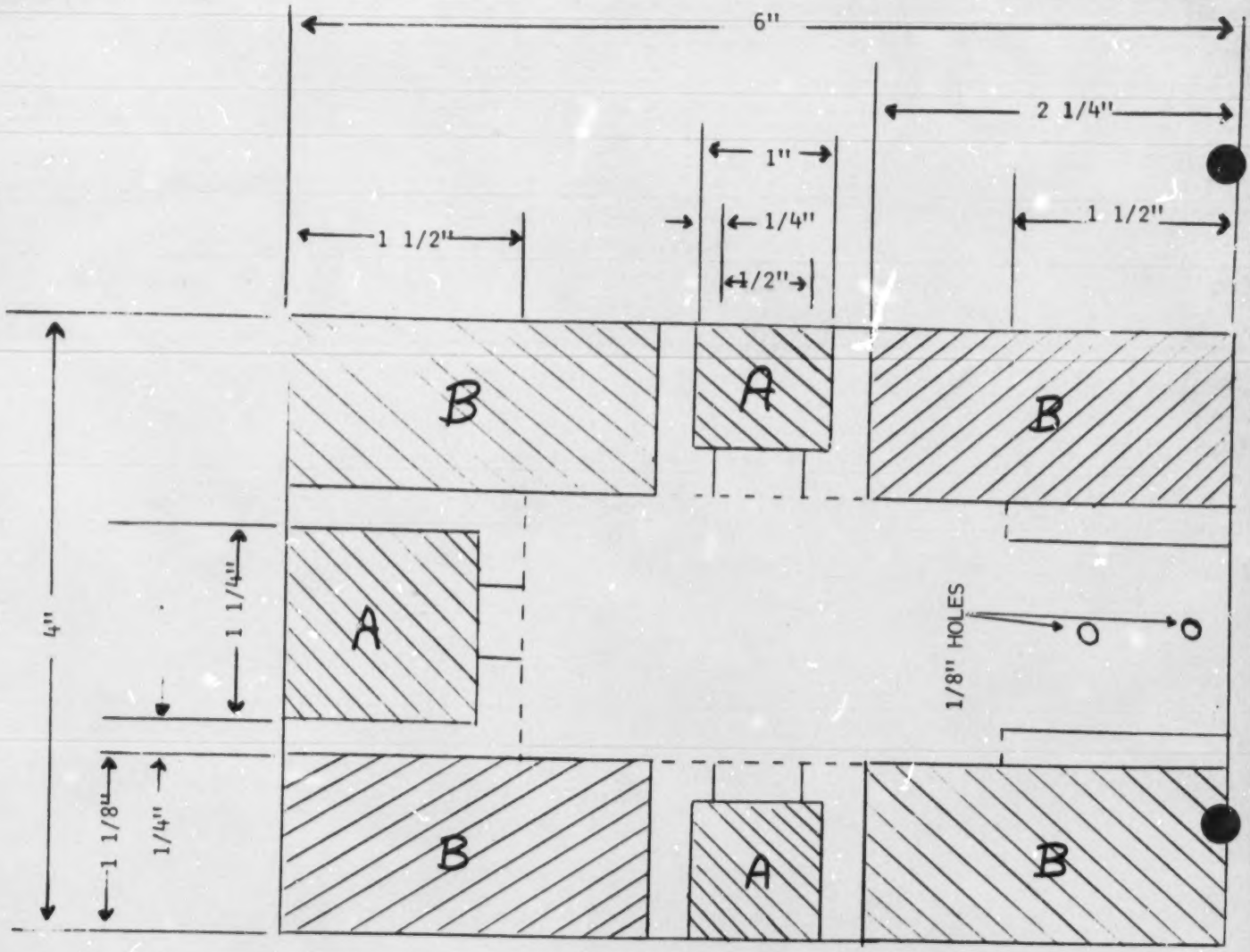


FIGURE 1

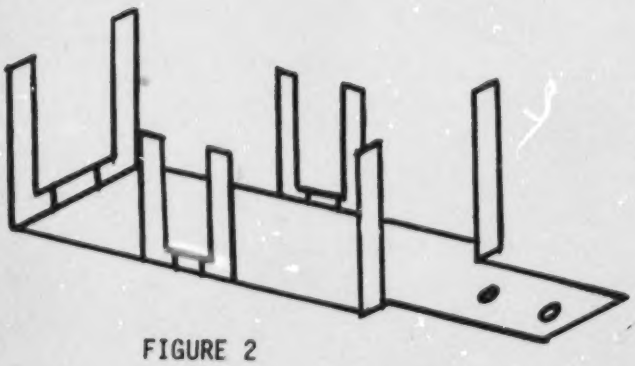


FIGURE 2

INSTRUCTIONS FOR THE MAKING OF GUARDS

The aluminum sheets are first formed into the shape shown in Figure 1. A suggested order of steps is:

1. Tape a number of sheets together to make a stack approximately 1" thick;
2. Using a milling machine, remove the three areas between the uprights (sections A);
3. Cut the six slots for the adhesive foil hold-down tabs and the two slots for the handle using a band saw;
4. Separate the sheets and, using a corner cutter, remove the four corners from each sheet (sections B);
5. Punch or drill the holes in the handles;
6. Remove all burrs;
7. Bend the uprights and adhesive foil hold-down tabs perpendicular to the rest of the guard.

The completed guard is shown in Figure 2.

LESSON 2

CONCEPT: The effects of particulates can vary from affecting the weather to increasing potential harm to human tissue.

MATERIALS:
1. G. E. silicone adhesive, SR-516
2. toluene, (for use as a thinner for the adhesive)
3. aluminum foil, at least .005" thick
4. paint brush, 1" wide (these are disposed of after use)
5. acetone, trichloroethylene, or some other organic cleaner
6. plastic bag (for each monitor)
7. paper clips (at least two for each monitor)
8. paper bag or cardboard box

PROCEDURE: *"Now that we know what particulates are, let's discuss what they can do."*

1. *"How can particulates affect the weather?"* (They can act as nucleation sites for the formation of fog; they absorb radiant energy normally transmitted through gases thereby producing possible "heat umbrellas")

2. *"How can particulates affect health?"*
   a. some particulates, such as hydrocarbons, may cause cancer
   b. particulates less than 2 to 3 microns in size can carry absorbed gases deep into the lungs where no mucous membranes exist to protect the tissues)

3. *"What else can particulates do?"*
   (they act as catalysts, especially iron oxides, to convert SO^2 to sulfuric acid)

4. *"What are some particulates associated with certain industries, and how are they harmful?"*
   a. BeO, possibly causes malignant tumors
   b. As, a poison and suspected to causing lung cancer
   c. Pb, a cumulative poison
   d. Asbestos, lung diseases including cancer
   e. Cd, respiratory poison and heart disease
   f. fluorides, Hg, Va, Ni, Mn, and Cr are also possibilities

5. *"We're now ready to make the adhesive foils that will catch these harmful particulates, and assemble the entire monitor."*

NOTE: The making of the adhesive foils and the assembly of the monitors should be conducted as close together as possible to minimize collection of particles before the start of the monitoring period.

MAKING OF ADHESIVE FOILS

PURPOSE: The adhesive foil provides the surface for particulate collection. The purpose of the foil is to provide a backing for the adhesive to allow weighing before and after exposure to the air.

PROCEDURES: The adhesive foil should be a form that is convenient to cut after the adhesive has been applied and dried. The best would probably be a roll or wide ribbon, but sheets will also work.

1. Make any marks on the aluminum foil that would help during the cutting step later on. The size for each foil after cutting should be 1 3/16" by 2 15/16" - the correct size should allow them to be easily placed in the guards but not so loosely that they could fall out once the hold-down tabs have been bent down. Mark a sample number in one corner of each section; this is done best with something that makes an impression in the foil rather than a pen or similar marker.

2. Clean the aluminum foil thoroughly with the acetone or other solvent; make sure to provide adequate ventilation during this and the next two steps.

3. Thin the silicone adhesive to a consistency that will allow easy application; do not thin excessively or obtaining a uniform coating on the foil may be difficult.

4. The adhesive should be applied in a room that is as dust-free as possible. Place a clean paper towel under each section of aluminum foil to catch any adhesive that may run off. Using a paint brush, apply the thinned silicone adhesive. Use enough adhesive to provide complete coverage, but do not use an exceptionally thick coating as this may impair solvent removal.

5. Dry the adhesive coated foils at least overnight in a relatively dust-free area, such as a clean closet or storeroom.

6. Cut the foil into individual sections. The cutting tool should be as sharp as possible to provide a clean cut through the adhesive layer; frequent sharpening may be required. A paper cutter is a convenient cutter since blocks could be set up next to it to allow cutting the sections to uniform size.

7. Weigh the foils to at least .001 gram and record the weighings on a master data sheet - a suggested form is included.

ASSEMBLY OF MONITOR

This procedure includes placing the adhesive foils in the guards and placing the completed assemblies in a protective enclosure. The protective enclosure not only helps to prevent physical damage to the monitors, but more important, it prevents particulates from accumulating on the adhesive foil before the start of the monitoring period.

PROCEDURES:

1. Carefully place the adhesive foil into the guard, and bend down the three hold-down tabs until they form an angle of approximagely 30 degrees with the foil.

2. Immediately place the monitor into a plastic bag, fold the open end over twice to seal the bag, and secure the folds with a couple of paper clips.

3. The plastic bags can then be placed in paper bags or, better yet, cardboard boxes for further protection.

MASTER DATA SHEET
(Sample)

Specimen No.	Initial Weight	Final Weight	Change in Weight	Sample Valid	Sample Invalid	Remarks

LESSON 3

CONCEPT: The main sources of particulates in order are fuel combustion in stationary sources, industrial processes, transportation, and solid waste disposal.

PROCEDURES: *"Let's discuss the sources of particulates so we can select good places to place our monitors."*

1. *"What are some sources of particulates?"*
   (listed on chart below)

2. *"What are the quantities of particulates emitted by these sources on a nationwide basis?"* (as of 1971)

a.	Stationary Sources (power plants & space heating)	8.9 million tons/year
b.	Industrial Processes (pulp and paper mills, iron and steel mills, petroleum refineries, smelters, chemical factories)	7.5 " " "
c.	Transportation	1.2 " " "
d.	Solid Waste Disposal	1.1 " " "
e.	Miscallaneous (controlled agriculture and forest burning, solvent and gasoline evaporation, accidental burning or coal refust piles and forest fires)	9.6 " " "

3. *"Do you think the relative percentages are representative of our area."*
   (No. Our stationary sources would probably be less due to electricity generation by hydroelectric plants rather than combustion plants)

4. *"Do you think the relative percentages would change at different times?"*
   (Yes. For example, stationary sources would increase their amounts of particulates during the winter, and transportation would increase theirs during rush hours)

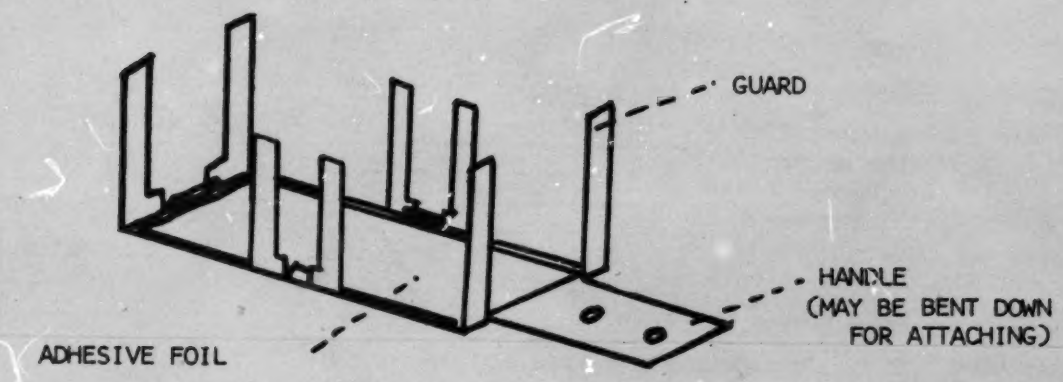
5. *"Keeping these sources in mind, and using the following cautionary notes, let's expose our monitors for the next thirty days."*

DISTRIBUTION OF MONITORS

Instructions should be given to those who will be exposing the monitors but who have not worked on their construction and so are not familiar with them. This will help prevent as much mishandling of the monitors as possible and help increase the percentage that will be valid. An instruction sheet, similar to that on the following page, is advisable. It may have to be rewirtten depending on the age level of those exposing the monitors. A data sheet should be given to the people receiving the monitors as well - sample data sheets follow the sample instruction sheet. A verbal presentation of the instruction and data sheets while distributing the monitors is highly recommended. Also, if a sample adhesive foil is circulated to allow participants to feel how sticky the adhesive is, they probably will not be tempted to touch their own monitors.

INSTRUCTIONS FOR USE OF ADHESIVE FOILS
(sample)

DESCRIPTION;



Many of these particulate monitors will be exposed in this area during the next 30 days. The small strip of aluminum foil has been coated with an adhesive and accurately weighed. It will be weighed again after exposure, and the gain will be due to particulates that were in the air -- this is one form of air pollution.

PROCEDURE:

1. Determine where to place your monitor. It should be in an open area, away from trees and buildings, and about five feet off the ground. The holes in the handle may be helpful in attaching the sampler to the place you have chosen. Be especially careful to not touch the adhesive foil.

2. Remove the monitor from the plastic bag using the handle only. Save the clear bag and the paper clips for returning the monitor.

3. Mount the monitor. Occasionally check the monitor. Keep the data sheet up to date.

4. After 30 days, return your monitor. Carefully put the monitor back in the plastic bag, roll the open end over a couple of times, and seal with the paper clips. Fold your data sheet and attach it to the plastic bag with the paper clips when returning.

DATA SHEET

Sample Number _____

Final Weight _____
Initial Weight _____
Change in Weight _____

Name of Participart _____
Home Address _____
Location of Monitor (if other than Home Address)
_____
How was monitor mounted?
Height above ground _____
Distance from nearest building _____
Sample attached to _____
How was it attached _____
Dates of exposure: From _____ to _____
Any observations after exposure _____
_____
_____

Did anything unusual happen to the sample during exposure? If so, what?
_____
_____
_____

Make sure to fill in the appropriate boxes below daily.

Days of Exposure	Date	Wind is Coming From	Wind Speed 1=calm 2=light 3=medium 4=strong	Amount of Rainfall 1 = none 2 = some 3 = a lot
1				
2				
3				
4				
5				
6				
7				
8				

Days of Exposure	Date	Wind is Coming From	Wind Speed 1 = calm 2 = light 3 = medium 4 = strong	Amount of Rainfall 1 = none 2 = some 3. = a lot
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

LESSON 4

CONCEPT: The types of particulates and their amounts vary widely across the country.

MATERIALS:
1. Map of area monitored
2. Graph paper
3. Map pins with different colored heads, different colored small flags, etc.

PROCEDURE: *"We're ready now to determine the quantity of particulates that fall in our area. Before we do, let's look at how some other cities compare."*

New York City, winter	335 tons/day
Los Angeles, aerosols from cars	40 tons/day
Kansas City, winter	67 tons/mile^2/month

"Now let's use the following procedures to determine the quantity of particulates that have fallen in our area."

EVALUATION OF MONITORS

When the monitors and data sheets have been returned, the evaluation should proceed as follows:

1. Look at the entire monitor assembly to see if it has been grossly mishandled - if it has, mark it as invalid on the master data sheet and mention why in the remarks section.

2. Carefully bend the hold-down tabs back to a perpendicular position and remove the adhesive foil; do not touch the adhesive foil during this step.

3. Reweigh the adhesive foil, again to the nearest .001 gram or better - record the value on the master data sheet.

4. Examine the adhesive foil for any foreign objects that may make it invalid, such as tree leaves, twigs, or needles, large insects, grass, pebbles, or large ashes - these indicate the monitor has not been properly exposed or handled, and should be recorded as invalid (NOTE: many smaller insects, such as gnats and mosquitos, usually do not affect the weights).

5. Read the completed data sheets to see if anything indicates an improperly exposed monitor, such as placement too close to a source of large particles; a trash barrel or the edge of a deck for example.

6. Make sure to mark whether or not the sample is valid and any remarks on the master data sheet.

7. Subtract the initial weight of the adhesive foil from the weight after exposure, and divide by the area of the foil (Example: if the weight after exposure was 1.9734 grams; the weight before exposure was 1.9612 grams; and the foil was 3 centimeters by 7.5 centimeters, the amount of particulate fall would be:

$$\frac{1.9734\ g - 1.9612\ g}{3\ cm \times 7.5\ cm} = .00054\ g/cm^2/month$$

Tnis can be converted to tons/sq. mile by multiplying by

$$28{,}400\ \frac{tons - cm^2}{g - mi^2} \qquad (.00054\ g/cm^2/mo.)(28{,}400\ \frac{tons - cm^2}{g - mi^2}) =$$

$$148\ tons/mi^2/month$$

It might be useful to change this density to one with more meaningful units, such as tons per square mile.

8. These results can be displayed on a map showing their location during exposure. Some type of color code could be used for different ranges of particulate-fall -- colored heads on pins or construction paper flags can be used.

9. A curve could also be drawn to show the frequency of certain ranges of particulate-fall. If you don't know a statistical way of presenting this information, one such method follows:

   a. subtract the lowest value from the highes value - this gives the range;
   b. divide the range by 15 -- this gives the interval (it is usually helpful to round off the interval to some number easier to manipulate;
   c. determine how many particulate fall values fall into each interval; and
   d. plot the results using the frequency (number of values in each interval) as the y-axis and the midpoints of each interval on the x-axis.

For Example:

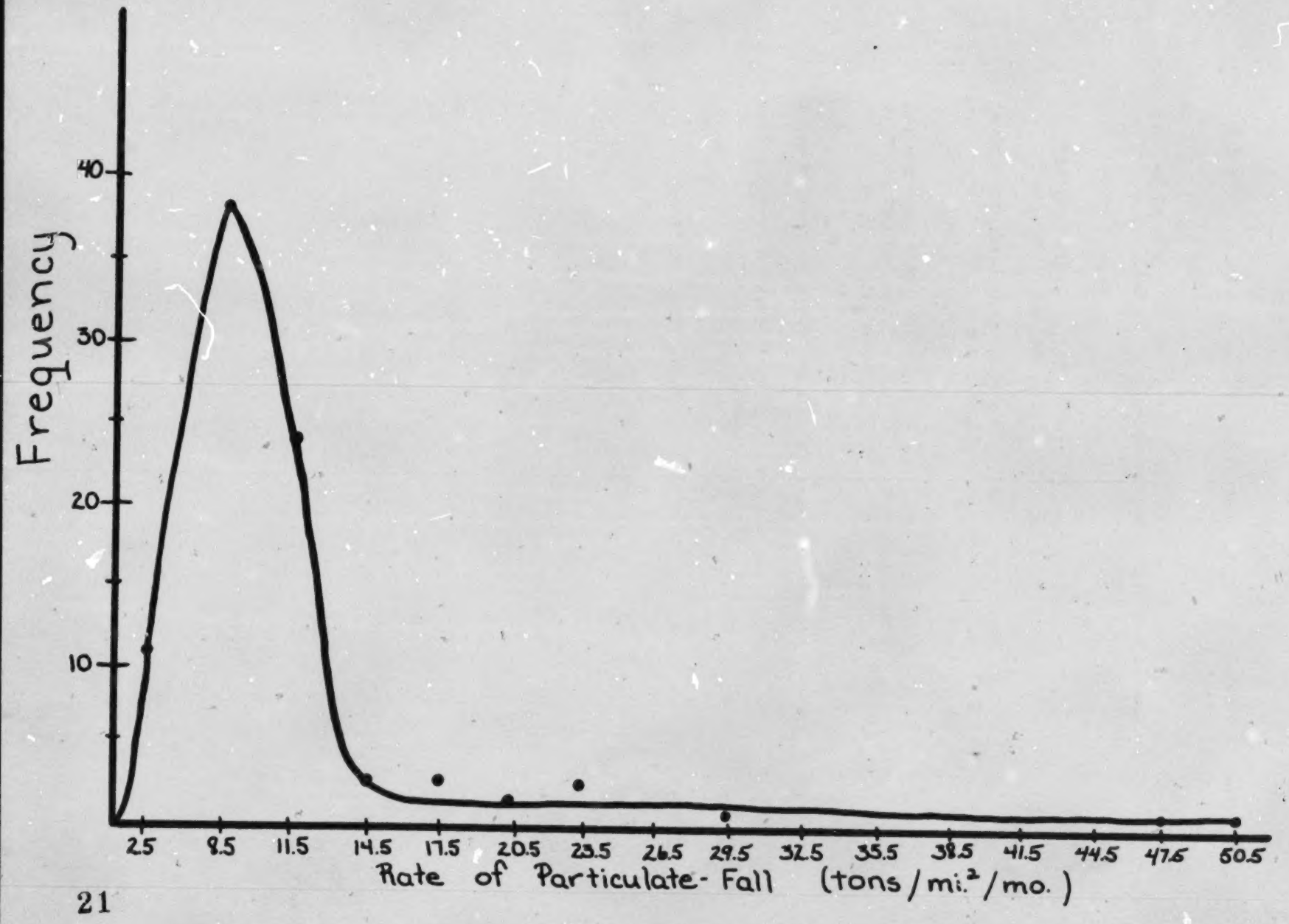
   a. Let's say the values varied from a high of 47 $tons/mi^2$ to a low of 1 ton/mi^2, the range would then be:
      $47\ tons/mi^2 - 1\ ton/mi^2 = 46\ tons/mi^2$

   b. To determine the interval, divide this by 15:
      $$\frac{46\ tons/mi^2}{15} = 3.06$$
      We'll round this off to 3 to make it easier to work with.

c. The intervals will then be: 1 to 4 ton/mi^2, 4 to 7 tons/mi^2, 7 to 10 tons/mi^2, etc. Let's say the number of monitors fell into the intervals in the following manner:

Interval, tons/mi^2	Frequency (# of monitors)	Midpoint, tons/mi^2
1 - 4	11	2.5
4 - 7	38	5.5
7 - 10	24	8.5
10 - 13	3	11.5
13 - 16	3	
16 - 19	2	
19 - 22	3	
25 - 28	0	
28 - 31	1	
31 - 34	0	
34 - 37	0	
37 - 40	0	
40 - 43	0	
43 - 46	1	
46 - 49	1	

d. Using the midpoints of each interval shown in the third column, the results would look like those on the following page.


Frequency
40
30
20
10
2.5
8.5
11.5
14.5
17.5
20.5
23.5
26.5
29.5
32.5
35.5
38.5
41.5
44.5
47.5
50.5
Rate of Particulate-Fall (tons/mi.²/mo.)

LESSON 5

CONCEPT: A number of ways to control particulates exist for the previously mentioned sources.

PROCEDURE: *"Let's look at the different sources of particulates we discussed before and name some methods of controlling their particulate output."*

1. Stationary Sources
   a. removal of particulates by filters, electrostatic precipitators, or cyclones that whirl them out through centrifugal force
   b. 99% of particulates from power plants can be removed for less than 1¢ on the average electric bill.

2. Industrial Processes
   a. essentially the same as those for stationary sources
   b. occasionally the collected particulates can become an important by-product for the industry

3. Transportation
   a. emission controls on engines or new forms of power to reduce hydrocarbons
   b. evaporative control devices to prevent aerosols from gas tanks and carburators from escaping.

4. Solid Waste Disposal
   a. sanitary land fill or efficient incineration